

	Type	L #	Hits	Search Text	DBs	Time Stamp
1	BRS	L1	173626	inert adj3 gas	USPAT; US-PGP UB; EPO; JPO; DERWEN T; IBM_TD B	2003/04/29 15:17
2	BRS	L2	725	ruthenium near4 gas	USPAT; US-PGP UB; EPO; JPO; DERWEN T; IBM_TD B	2003/04/29 15:19
3	BRS	L3	202698	oxidation	USPAT	2003/04/29 15:19
4	BRS	L4	401258	oxidation	USPAT; US-PGP UB; EPO; JPO; DERWEN T; IBM_TD B	2003/04/29 15:19
5	BRS	L5	1	1 same 2 same 4	USPAT; US-PGP UB; EPO; JPO; DERWEN T; IBM_TD B	2003/04/29 15:20
6	BRS	L6	133	ruthenium adj3 precursor	USPAT; US-PGP UB; EPO; JPO; DERWEN T; IBM_TD B	2003/04/29 15:20

	Type	L #	Hits	Search Text	DBs	Time Stamp
7	BRS	L7	0	1 same 4 same 6	USPAT; US-PGP UB; EPO; JPO; DERWEN T; IBM_TD B	2003/04/29 15:20
8	BRS	L8	222663	"O.sub.2" or "N.sub.20" or "H.sub.20" or "NO.sub.2" or "O.sub.3"	USPAT; US-PGP UB; EPO; JPO; DERWEN T; IBM_TD B	2003/04/29 15:22
9	BRS	L9	2	1 same 2 same 8	USPAT; US-PGP UB; EPO; JPO; DERWEN T; IBM_TD B	2003/04/29 15:32
10	BRS	L10	591935	"N.sub.2" or He or Ar or Ne or Xe	USPAT; US-PGP UB; EPO; JPO; DERWEN T; IBM_TD B	2003/04/29 15:33
11	BRS	L11	24	2 same 8 same 10	USPAT; US-PGP UB; EPO; JPO; DERWEN T; IBM_TD B	2003/04/29 15:47

DOCUMENT-IDENTIFIER: US 20020058415 A1

TITLE: Methods for forming rough  
ruthenium-containing layers  
and structures/methods using same

----- KWIC -----

[0047] Preferably, the deposition rate for forming a rough ruthenium layer 14 while maintaining step coverage is a deposition rate in the range of about 100 .ANG./minute to about 500 .ANG./minute. More preferably, the deposition rate is in a range of about 200 .ANG./minute to about 300 .ANG./minute. Yet further, to maintain the step coverage with a high concentration of ruthenium-containing precursor provided to the reaction chamber, preferably, a flow rate of about 100 sccm to about 500 sccm of carrier gas (e.g., He, O.sub.2, or any other gas that is non-reactive with the precursor) through a ruthenium-containing precursor held in a bubbler reservoir at a temperature of about 15.degree. C. to about 100.degree. C. is provided to the chamber. More preferably, the flow rate of carrier gas through the ruthenium-containing precursor to the reaction chamber is at a rate in the range of about 150 sccm to about 250 sccm.

DOCUMENT-IDENTIFIER: US 20020055254 A1

TITLE: Semiconductor device manufacturing  
method and substrate  
processing apparatus

----- KWIC -----

[0029] Next, reference will be made to the timing of supplying the gases, which is characteristic of the semiconductor device manufacturing method according to the present invention, while referring to FIG. 1. First, as described above, the silicon wafer 30 disposed on the susceptor 29 in the semiconductor manufacturing apparatus is lifted to the deposition position in the reaction chamber 32, where the silicon wafer 30 is heated up to a temperature of 290-350.degree. C. by means of the heater 27. Subsequently, an N.sub.2 gas, which does not contribute to deposition reactions, is supplied to the reaction chamber in an amount of k sccm. Here, note that the amount of the gas supply k sccm is an amount of supply by which the pressure in the reaction chamber 32 can be held in a range of 60-180 Pa. Then, the amount of the N.sub.2 gas supplied is adjusted to a range of 1,250-1,500 sccm, and the pressure in the reaction chamber 32 is raised to a value ranging from 60 to 4,000 Pa. Thereafter, a raw material gas containing ruthenium such as, for example, a gas evaporated from a liquid raw material Ru(C.sub.2H.sub.5C.sub.5H.sub.4).su- b.2(referred to as bisethyl-cyclopentadienyl-ruthenium), is supplied from the ruthenium raw gas supply pipe 24a to the reaction chamber 32 in an amount of supply ranging from 0.005 to 0.12 sccm while decreasing the amount of supply of the N.sub.2 gas,

thereby holding the pressure in the reaction chamber 32 at a range of 60-4,000 Pa. Subsequently, after the amount of supply of the ruthenium raw gas has become constant or steady, an oxygen-containing gas containing oxygen such as, for instance, an O.sub.2 gas, is supplied to the reaction chamber from the oxygen-containing gas supply pipe 24b in an amount of supply ranging from 40 to 1,500 sccm while decreasing the amount of supply of the N.sub.2 gas to a value ranging from 0 to 710 sccm, thereby holding the pressure in the reaction chamber 32 in a range of 60-4,000 Pa. Here, note that an O.sub.3 gas or an N.sub.2O gas may be used as the oxygen-containing gas. In this manner, the deposition of ruthenium films is initiated. That is, the ruthenium raw gas is supplied prior to or earlier than the oxygen-containing gas, so that the oxygen ratio, i.e., the volume ratio of the oxygen-containing gas to the ruthenium raw gas, before the start of deposition of the ruthenium films is controlled to be smaller than the oxygen ratio at the time of deposition, and not greater than a value at which there takes place no deposition reaction in which ruthenium is separated from the ruthenium raw gas. Then, the amount of the oxygen-containing gas to be supplied is decreased, and thereafter the amount of the ruthenium raw gas to be supplied is also decreased. Thus, after the supply of the oxygen-containing gas is stopped, the supply of the ruthenium raw gas is also stopped, and the amount of the N.sub.2 gas to be supplied is increased to a value ranging from 1,250 to 1,500 sccm, thereby holding the pressure in the reaction chamber 32 at a value ranging from 60 to 4,000 Pa. In this manner, the deposition of the ruthenium films is completed. After this, the amount of the N.sub.2 gas to be supplied is decreased to a value of k

sccm, whereby the  
pressure in the reaction chamber 32 is held at a level in  
the range of 60-180  
Pa.

US-PAT-NO: 6461961

DOCUMENT-IDENTIFIER: US 6461961 B1

TITLE: Methods of manufacturing  
semiconductor devices with  
ruthenium films formed by CVD using  
an oxygen-containing  
reactant gas

----- KWIC -----

Next, reference will be made to the timing of supplying the gases, which is characteristic of the semiconductor device manufacturing method according to the present invention, while referring to FIG. 1. First, as described above, the silicon wafer 30 disposed on the susceptor 29 in the semiconductor manufacturing apparatus is lifted to the deposition position in the reaction chamber 32, where the silicon wafer 30 is heated up to a temperature of 290-350.degree. C. by means of the heater 27. Subsequently, an N.sub.2 gas, which does not contribute to deposition reactions, is supplied to the reaction chamber in an amount of k sccm. Here, note that the amount of the gas supply k sccm is an amount of supply by which the pressure in the reaction chamber 32 can be held in a range of 60-180 Pa. Then, the amount of the N.sub.2 gas supplied is adjusted to a range of 1,250-1,500 sccm, and the pressure in the reaction chamber 32 is raised to a value ranging from 60 to 4,000 Pa. Thereafter, a raw material gas containing ruthenium such as, for example, a gas evaporated from a liquid raw material Ru(C.sub.2 H.sub.5 C.sub.5 H.sub.4).sub.2 (referred to as bisethyl-cyclopentadienyl-ruthenium), is supplied from the

ruthenium raw gas supply pipe 24a to the reaction chamber 32 in an amount of supply ranging from 0.005 to 0.12 sccm while decreasing the amount of supply of the N.sub.2 gas, thereby holding the pressure in the reaction chamber 32 at a range of 60-4,000 Pa. Subsequently, after the amount of supply of the ruthenium raw gas has become constant or steady, an oxygen-containing gas containing oxygen such as, for instance, an O.sub.2 gas, is supplied to the reaction chamber from the oxygen-containing gas supply pipe 24b in an amount of supply ranging from 40 to 1,500 sccm while decreasing the amount of supply of the N.sub.2 gas to a value ranging from 0 to 710 sccm, thereby holding the pressure in the reaction chamber 32 in a range of 60-4,000 Pa. Here, note that an O.sub.3 gas or an N.sub.2 O gas may be used as the oxygen-containing gas. In this manner, the deposition of ruthenium films is initiated. That is, the ruthenium raw gas is supplied prior to or earlier than the oxygen-containing gas, so that the oxygen ratio, i.e., the volume ratio of the oxygen-containing gas to the ruthenium raw gas, before the start of deposition of the ruthenium films is controlled to be smaller than the oxygen ratio at the time of deposition, and not greater than a value at which there takes place no deposition reaction in which ruthenium is separated from the ruthenium raw gas. Then, the amount of the oxygen-containing gas to be supplied is decreased, and thereafter the amount of the ruthenium raw gas to be supplied is also decreased. Thus, after the supply of the oxygen-containing gas is stopped, the supply of the ruthenium raw gas is also stopped, and the amount of the N.sub.2 gas to be supplied is increased to a value ranging from 1,250 to 1,500 sccm, thereby holding the pressure in the reaction chamber 32 at



a value ranging from  
60 to 4,000 Pa. In this manner, the deposition of the  
ruthenium films is  
completed. After this, the amount of the N.sub.2 gas to be  
supplied is  
decreased to a value of k sccm, whereby the pressure in the  
reaction chamber 32  
is held at a level in the range of 60-180 Pa.

US-PAT-NO: 6429127

DOCUMENT-IDENTIFIER: US 6429127 B1

TITLE: Methods for forming rough  
ruthenium-containing layers  
and structures/methods using same

----- KWIC -----

Preferably, the deposition rate for forming a rough ruthenium layer 14 while maintaining step coverage is a deposition rate in the range of about 100 .ANG./minute to about 500 .ANG./minute. More preferably, the deposition rate is in a range of about 200 .ANG./minute to about 300 .ANG./minute. Yet further, to maintain the step coverage with a high concentration of ruthenium-containing precursor provided to the reaction chamber, preferably, a flow rate of about 100 sccm to about 500 sccm of carrier gas (e.g., He, O.sub.2, or any other gas that is non-reactive with the precursor) through a ruthenium-containing precursor held in a bubbler reservoir at a temperature of about 15.degree. C. to about 100.degree. C. is provided to the chamber. More preferably, the flow rate of carrier gas through the ruthenium-containing precursor to the reaction chamber is at a rate in the range of about 150 sccm to about 250 sccm.

US-PAT-NO: 6335551

DOCUMENT-IDENTIFIER: US 6335551 B1

TITLE: Thin film capacitor having an  
improved bottom electrode  
and method of forming the same

----- KWIC -----

A first embodiment according to the present invention will be described in detail with reference to FIG. 4 which is a fragmentary cross sectional elevation view illustrative of a first novel thin film capacitor having an improved bottom electrode formed over a semiconductor substrate for a semiconductor integrated circuit. A  $\text{SiO}_2$  passivation film 2 is provided on a GaAs substrate 1. A Ti layer 3 having a thickness of 10 nanometers is deposited as a contact layer on a selected region of the  $\text{SiO}_2$  passivation film 2 by a sputtering method at room temperature. The GaAs substrate 1 is cooled at a temperature of  $-100^\circ\text{C}$ . indirectly with a liquid nitrogen before an amorphous ruthenium oxide thin film having a thickness of 100 nanometers is deposited on the Ti contact layer 3 by a reactive sputtering method using an Ar-75%  $\text{O}_2$  mixture gas to form an amorphous ruthenium oxide bottom electrode 4-1 on the Ti contact layer 3. An  $\text{SrTiO}_3$  thin dielectric film 7 having a thickness of 200 nanometers is deposited on a selected region of the amorphous ruthenium oxide bottom electrode 4-1 by an RF-sputtering method at a temperature of  $200^\circ\text{C}$ . A Pt top electrode 8 is provided on the  $\text{SrTiO}_3$  thin dielectric film 7. A  $\text{SiO}_2$  interlayer insulator 5 is

entirely provided which extends over the Pt top electrode 8, the SrTiO<sub>3</sub> thin dielectric film 7, the amorphous ruthenium oxide bottom electrode 4-1 and the SiO<sub>2</sub> passivation film 2. The SiO<sub>2</sub> interlayer insulator 5 has contact holes positioned over the Pt top electrode 8 and the amorphous ruthenium oxide bottom electrode 4-1. A first Au interconnection layer 6-1 is provided over the SiO<sub>2</sub> interlayer insulator 5 and within the contact hole positioned over the amorphous ruthenium oxide bottom electrode 4-1, so that the first Au interconnection layer 6 is in contact with the amorphous ruthenium oxide bottom electrode 4-1. A second Au interconnection layer 6-2 is provided over the SiO<sub>2</sub> interlayer insulator 5 and within the contact hole positioned over the Pt top electrode 8, so that the second Au interconnection layer 6 is in contact with the Pt top electrode 8.

A fourth embodiment according to the present invention will be described in detail with reference to FIG. 8 which is a fragmentary cross sectional elevation view illustrative of a fourth novel thin film capacitor having an improved bottom electrode formed over a semiconductor substrate for a semiconductor integrated circuit. A TiSi<sub>2</sub> first diffusion barrier layer 10 is provided on a Si substrate 9. A TiN second diffusion barrier layer 11 is provided on the TiSi<sub>2</sub> first diffusion barrier layer 10. An Ir third diffusion barrier layer 12a is provided on the TiN second diffusion barrier layer 11. The Si substrate 9 is cooled at a temperature of -100.degree. C. indirectly with a liquid nitrogen before an amorphous ruthenium oxide thin film is deposited on the Ir third diffusion barrier layer 12a by a reactive sputtering method using an Ar-75% O<sub>2</sub> mixture gas to form an amorphous

ruthenium oxide bottom electrode 13a on the Ir third diffusion barrier layer  
 12a. A (Ba.sub.0.5 Sr.sub.0.5)TiO.sub.3 first thin dielectric film 14 having a thickness of 10 nanometers is deposited on the amorphous ruthenium oxide bottom electrode 13a by an RF-sputtering method at a temperature of 300.degree. C., whereby a smooth interface with a small roughness is formed between the amorphous ruthenium oxide bottom electrode 13a and the (Ba.sub.0.5 Sr.sub.0.5)TiO<sub>3</sub> first thin dielectric film 14. A (Ba.sub.0.5 Sr.sub.0.5)TiO.sub.3 second thin dielectric film 15 having a thickness of 200 nanometers is deposited on the (Ba.sub.0.5 Sr.sub.0.5)TiO.sub.3 first thin dielectric film 14 by an RF-sputtering method at a higher temperature of 450.degree. C., whereby the above amorphous ruthenium oxide bottom electrode 13a is crystallized to form a single crystal ruthenium oxide bottom electrode 13a. Since, however, the smooth interface has already been defined between the amorphous ruthenium oxide bottom electrode 13a and the (Ba.sub.0.5 Sr.sub.0.5)TiO.sub.3 first thin dielectric film 14, the interface between the single crystal ruthenium oxide bottom electrode 13a and the (Ba.sub.0.5 Sr.sub.0.5)TiO.sub.3 first thin dielectric film 14 remains smooth. Namely, the high flatness of the surface of the single crystal ruthenium oxide bottom electrode 13a can be obtained. Since, further, the (Ba.sub.0.5 Sr.sub.0.5)TiO.sub.3 second thin dielectric film 15 is formed by the higher temperature than when the (Ba.sub.0.5 Sr.sub.0.5)TiO.sub.3 first thin dielectric film 14 is formed, then the (Ba.sub.0.5 Sr.sub.0.5)TiO.sub.3 second thin dielectric film 15 has a higher dielectric constant than the (Ba.sub.0.5 Sr.sub.0.5)TiO.sub.3 first thin dielectric film 14. Since, furthermore, the

(Ba.sub.0.5 Sr.sub.0.5)TiO.sub.3 second thin dielectric film 15 is much thicker than the (Ba.sub.0.5 Sr.sub.0.5)TiO.sub.3 first thin dielectric film 14, a dielectric constant of the capacitor largely depends upon the higher dielectric constant of the (Ba.sub.0.5 Sr.sub.0.5)TiO.sub.3 second thin dielectric film 15. Thus, the above structure makes it possible to obtain both the required smooth interface between the bottom electrode and the dielectric film of the capacitor and the required high dielectric constant of the capacitor. An Ru top electrode 16 is provided on the (Ba.sub.0.5 Sr.sub.0.5)TiO.sub.3 second thin dielectric film 15.

A fifth embodiment according to the present invention will be described in detail with reference to FIG. 10 which is a fragmentary cross sectional elevation view illustrative of a fifth novel thin film capacitor having an improved bottom electrode formed over a semiconductor substrate for a semiconductor integrated circuit. A TiSi.sub.2 first diffusion barrier layer 10 is provided on a Si substrate 9. A TiN second diffusion barrier layer 11 is provided on the TiSi.sub.2 first diffusion barrier layer 10. An Ru third diffusion barrier layer 12a is provided on the TiN second diffusion barrier layer 11. The Si substrate 9 is cooled at a temperature of -100.degree. C. indirectly with a liquid nitrogen before an amorphous ruthenium oxide thin film is deposited on the Ru third diffusion barrier layer 12 by a reactive sputtering method using an Ar-75% O.sub.2 mixture gas to form an amorphous strontium ruthenium oxide SrRuO.sub.3 layer on the Ru third diffusion barrier layer 12. A Pb(Zr.sub.0.48 Ti.sub.0.52)O.sub.3 thin film having a thickness of 200 nanometers is deposited on the amorphous strontium ruthenium oxide

SrRuO<sub>3</sub> layer by an RF-sputtering method at a temperature of 300.degree.  
 C., before the whereby a smooth interface with a small roughness is formed between the Pb(Zr<sub>0.48</sub>Ti<sub>0.52</sub>)O<sub>3</sub> thin film is subjected to a rapid thermal annealing in an oxygen atmosphere at a temperature of 600.degree.  
 C. for 30 seconds to cause a crystallization of the amorphous strontium ruthenium oxide SrRuO<sub>3</sub> layer thereby to form a strontium ruthenium oxide SrRuO<sub>3</sub> bottom electrode 17-1 and also to form a Pb(Zr<sub>0.48</sub>Ti<sub>0.52</sub>)O<sub>3</sub> thin dielectric film 18 on the strontium ruthenium oxide SrRuO<sub>3</sub> bottom electrode 17-1. An Ru top electrode 16 is provided on the Pb(Zr<sub>0.48</sub>Ti<sub>0.52</sub>)O<sub>3</sub> thin dielectric film 18.  
 During the deposition process of the Pb(Zr<sub>0.48</sub>Ti<sub>0.52</sub>)O<sub>3</sub> thin film at the temperature of 300.degree. C., no crystallization is caused to the amorphous strontium ruthenium oxide SrRuO<sub>3</sub> layer, for which reason the smooth surface of the amorphous strontium ruthenium oxide SrRuO<sub>3</sub> layer remains unchanged, whereby the smooth interface can be obtained between the amorphous strontium ruthenium oxide SrRuO<sub>3</sub> bottom electrode 17-1 and the amorphous Pb(Zr<sub>0.48</sub>Ti<sub>0.52</sub>)O<sub>3</sub> thin film. During the subsequent rapid thermal annealing at the temperature of 600.degree. C. for forming the Pb(Zr<sub>0.48</sub>Ti<sub>0.52</sub>)O<sub>3</sub> thin dielectric film 18, the amorphous strontium ruthenium oxide SrRuO<sub>3</sub> layer is crystallized to form the strontium ruthenium oxide SrRuO<sub>3</sub> bottom electrode 17-1. Notwithstanding, the smooth interface between the amorphous strontium ruthenium oxide SrRuO<sub>3</sub> layer and the Pb(Zr<sub>0.48</sub>Ti<sub>0.52</sub>)O<sub>3</sub> thin film has already been defined, for which reason the smooth interface can be obtained

between the strontium ruthenium oxide  $\text{SrRuO}_{0.3}$  bottom electrode 17-1 and the  $\text{Pb}(\text{Zr}_{0.48}\text{Ti}_{0.52})\text{O}_{0.3}$  thin dielectric film 18. Further, the  $\text{Pb}(\text{Zr}_{0.48}\text{Ti}_{0.52})\text{O}_{0.3}$  thin dielectric film 18 is formed by the high temperature annealing, for which reason the  $\text{Pb}(\text{Zr}_{0.48}\text{Ti}_{0.52})\text{O}_{0.3}$  thin dielectric film 18 has a high dielectric constant. Thus, the above structure makes it possible to obtain both the required smooth interface between the bottom electrode and the dielectric film of the capacitor and the required high dielectric constant of the capacitor.

A sixth embodiment according to the present invention will be described in detail with reference to FIG. 11 which is a fragmentary cross sectional elevation view illustrative of a sixth novel thin film capacitor having an improved bottom electrode formed over a semiconductor substrate for a semiconductor integrated circuit. A  $\text{TiSi}_{0.2}$  first diffusion barrier layer 10 is provided on a Si substrate 9. A TiN second diffusion barrier layer 11 is provided on the  $\text{TiSi}_{0.2}$  first diffusion barrier layer 10. An Ru third diffusion barrier layer 12a is provided on the TiN second diffusion barrier layer 11. The Si substrate 9 is cooled at a temperature of  $-100^{\circ}\text{C}$ . indirectly with a liquid nitrogen before an amorphous ruthenium oxide thin film is deposited on the Ru third diffusion barrier layer 12 by a reactive sputtering method using an  $\text{Ar}-75\% \text{O}_{0.2}$  mixture gas to form an amorphous strontium ruthenium oxide  $\text{SrRuO}_{0.3}$  layer including 5 at % of Mg on the Ru third diffusion barrier layer 12. A  $\text{Pb}(\text{Zr}_{0.48}\text{Ti}_{0.52})\text{O}_{0.3}$  thin film having a thickness of 200 nanometers is deposited on the 5 at % Mg-containing amorphous strontium ruthenium oxide  $\text{SrRuO}_{0.3}$  layer by an



RF-sputtering method at a temperature of 300.degree. C.,  
 before the whereby a  
 smooth interface with a small roughness is formed between  
 the Pb(Zr.sub.0.48  
 Ti.sub.0.52)O.sub.3 thin film is subjected to a rapid  
 thermal annealing in an  
 oxygen atmosphere at a temperature of 600.degree. C. for  
 30 seconds to cause a  
 crystallization of the 5 at % Mg-containing amorphous  
 strontium ruthenium oxide  
 SrRuO.sub.3 layer thereby to form a 5 at % Mg-containing  
 strontium ruthenium  
 oxide SrRuO.sub.3 bottom electrode 17-2 and also to form a  
 Pb(Zr.sub.0.48  
 Ti.sub.0.52)O.sub.3 thin dielectric film 18 on the 5 at %  
 Mg-containing  
 strontium ruthenium oxide SrRuO.sub.3 bottom electrode  
 17-2. An Ru top  
 electrode 16 is provided on the Pb(Zr.sub.0.48  
 Ti.sub.0.52)O.sub.3 thin  
 dielectric film 18. During the deposition process of the  
 Pb(Zr.sub.0.48  
 Ti.sub.0.52)O.sub.3 thin film at the temperature of  
 300.degree. C., no  
 crystallization is caused to the 5 at % Mg-containing  
 amorphous strontium  
 ruthenium oxide SrRuO.sub.3 layer, for which reason the  
 smooth surface of the 5  
 at % Mg-containing amorphous strontium ruthenium oxide  
 SrRuO.sub.3 layer  
 remains unchanged, whereby the smooth interface can be  
 obtained between the 5  
 at % Mg-containing amorphous strontium ruthenium oxide  
 SrRuO.sub.3 bottom  
 electrode 17-2 and the amorphous Pb(Zr.sub.0.48  
 Ti.sub.0.52)O.sub.3 thin film.  
 During the subsequent rapid thermal annealing at the  
 temperature of 600.degree.  
 C. for forming the Pb(Zr.sub.0.48 Ti.sub.0.52)O.sub.3 thin  
 dielectric film 18,  
 the 5 at % Mg-containing amorphous strontium ruthenium  
 oxide SrRuO.sub.3 layer  
 is crystallized to form the 5 at % Mg-containing strontium  
 ruthenium oxide  
 SrRuO.sub.3 bottom electrode 17-2. Notwithstanding, the  
 smooth interface  
 between the 5 at % Mg-containing amorphous strontium  
 ruthenium oxide

SrRuO<sub>0.3</sub> layer and the Pb(Zr<sub>0.48</sub> Ti<sub>0.52</sub>)O<sub>0.3</sub> thin film has already been defined, for which reason the smooth interface can be obtained between the 5 at % Mg-containing strontium ruthenium oxide SrRuO<sub>0.3</sub> bottom electrode 17-2 and the Pb(Zr<sub>0.48</sub> Ti<sub>0.52</sub>)O<sub>0.3</sub> thin dielectric film 18. Further, the Pb(Zr<sub>0.48</sub> Ti<sub>0.52</sub>)O<sub>0.3</sub> thin dielectric film 18 is formed by the high temperature annealing, for which reason the Pb(Zr<sub>0.48</sub> Ti<sub>0.52</sub>)O<sub>0.3</sub> thin dielectric film 18 has a high dielectric constant. Thus, the above structure makes it possible to obtain both the required smooth interface between the bottom electrode and the dielectric film of the capacitor and the required high dielectric constant of the capacitor.

US-PAT-NO: 6287934

DOCUMENT-IDENTIFIER: US 6287934 B1

TITLE: Capacitor structure of semiconductor  
memory cell and  
method for fabricating capacitor  
structure of  
semiconductor cell

----- KWIC -----

Subsequently, DC sputtering is performed using Ru  
(ruthenium) as the and  
O.sub.2 /Ar as the process gas to form the lower electrode  
layer 21A made of  
RuO.sub.2 on the entire surface involving the insulation  
material layer 40.  
The lower electrode layer 21A is then dry-etched by RIE  
using O.sub.2  
/Cl.sub.2. In this manner, the semi-spherical insulation  
material layer 40  
made of SiN, and the lower electrode made of the lower  
electrode layer 21A  
stacked on the insulation material layer 40, can be  
obtained. Note here that  
dry-etching of the lower electrode layer 21A is conducted  
for patterning the  
lower electrode layer 21A, and not for shaping the lower  
electrode layer 21  
semi-spherical. The surface of the lower electrode layer  
21A on which the  
ferroelectric thin film should be made is covered by the  
resist material during  
etching of the lower electrode layer 21A. Therefore, the  
ferroelectric thin  
film can be formed on the lower electrode layer 21A  
maintaining its original  
surface condition, and deterioration in P-E hysteresis loop  
characteristics of  
the ferroelectric thin film can be prevented.

DOCUMENT-IDENTIFIER: US 20020190276 A1

TITLE: Process for the formation of  
RuSixOy-containing barrier  
layers for high-k dielectrics

----- KWIC -----

[0076] More specifically, deposition of monolayers is accomplished in a CVD chamber, as previously described with reference to the CVD deposition method, but with the addition of pulsing valves to allow the switching between the precursor and purge gas and the SiH.sub.4 (Si.sub.2H.sub.6) and purge gas. Bubblers, however, are not required since carrier gases may or may not be used, depending on the configuration of the vacuum system. For this example, a simple storage ampule with a single outlet and no inlet is used. As with the CVD method, C.sub.6H.sub.8Ru(CO).sub.3 is used as the ruthenium precursor. The deposition temperature of the wafer surface is 50-250 degrees C. and the reaction chamber is kept at a variable pressure range of about 0.5 torr to about 0.0001 torr. The reaction chamber is fully opened to the pumps of the vacuum system to create a vacuum in the CVD chamber and the ruthenium precursor gas is introduced at low pressure, preferably about 0.0001 torr. Introduction of the ruthenium precursor gas under these conditions will result in the deposition of, at most, a monolayer of ruthenium over the surface of the wafer. A purge cycle is then initiated by introducing a nonreactive gas, such as He or Ar, at a volumetric flow rate of about 50 sccm into the reaction chamber at 0.5 torr. It is understood that any suitable nonreactive gas may be used and that

DOCUMENT-IDENTIFIER: US 20010039115 A1

TITLE: Method and apparatus for  
manufacturing semiconductor  
devices

----- KWIC -----

[0035] In addition, the ratio of the flow rate of the ruthenium raw gas to the flow rate of the gas containing oxygen atoms (i.e., oxygen (O.sub.2), ozone (O.sub.3), etc.) is not particularly limited but can be properly determined according to the kind of the films (i.e., ruthenium films or ruthenium oxide films) formed on a substrate. Also, the carrier gas, being caused to flow through the carrier gas pipe 11 for transportation of the ruthenium raw gas, can be properly selected from known ones, and for instance, an inert gas such as a nitrogen (N.sub.2) gas, an argon (Ar) gas or the like may be used for such a purpose.

DOCUMENT-IDENTIFIER: US 20020187632 A1

TITLE: Process for the formation of  
RuSixOy-containing barrier  
layers for high-k dielectrics

----- KWIC -----

[0078] More specifically, deposition of monolayers is accomplished in a CVD chamber, as previously described with reference to the CVD deposition method, but with the addition of pulsing valves to allow the switching between the precursor and purge gas and the SiH<sub>4</sub> (Si<sub>2</sub>H<sub>6</sub>) and purge gas. Bubblers, however, are not required since carrier gases may or may not be used, depending on the configuration of the vacuum system. For this example, a simple storage ampule with a single outlet and no inlet is used. As with the CVD method, C<sub>6</sub>H<sub>8</sub>Ru(CO)<sub>3</sub> is used as the ruthenium precursor. The deposition temperature of the wafer surface is 50-250 degrees C. and the reaction chamber is kept at a variable pressure range of about 0.5 torr to about 0.0001 torr. The reaction chamber is fully opened to the pumps of the vacuum system to create a vacuum in the CVD chamber and the ruthenium precursor gas is introduced at low pressure, preferably about 0.0001 torr. Introduction of the ruthenium precursor gas under these conditions will result in the deposition of, at most, a monolayer of ruthenium over the surface of the wafer. A purge cycle is then initiated by introducing a nonreactive gas, such as He or Ar, at a volumetric flow rate of about 50 sccm into the reaction chamber at 0.5 torr. It is understood that any suitable nonreactive gas may be used and that

the nonreactive gas may be introduced at a rate of between about 0.1 sccm to about 500 sccm to optimize system conditions. Silane or disilane is introduced into the reaction chamber at a rate of about 5 sccm, which results in the deposition of a silicon monolayer over the previously deposited ruthenium monolayer. This is followed by a purge cycle of nonreactive gas, as previously described. It is understood that oxygen can be added as a separate oxygen/purge cycle as needed for every individual cycle in order to give the required oxygen content. In general, however, sufficient oxygen is available from background O.sub.2 and H.sub.2O in the chamber to oxidize the underlying RuSi.sub.x layer formed in the preceding steps. The monolayer of adsorbed precursor from the initial precursor deposition step will react directly when exposed to the reaction gas in the third step of the foregoing dose precursor/purge/dose reaction gas/purge sequence, which results in controlled deposition of one or more RuSi.sub.xO.sub.y-containing barrier monolayers.